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Childhood Asthma and Indoor Environmental Risk Factors

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In a case-control study carried out in Montréal, Québec, Canada, between 1988 and 1990, indoor environmental factors were studied in relation to the incidence of asthma among 3- and 4-year-old children. Cases (n = 457), whose parents were recruited at a hospital emergency room, were children who had a first-time diagnosis of asthma (*International Classification of Diseases*, Ninth Revision, code 493) made by a pediatrician. Controls (n = 457) were chosen from family allowance files and were matched with case children on age and census tract. A telephone interview was administered to the children's parents. A 20% feasibility subsample was chosen to wear a nitrogen dioxide monitoring badge during a 24-hour period. Multiple conditional logistic regression analysis showed that after personal susceptibility factors were controlled for, the following were independent risk factors for asthma: the mother's heavy smoking (odds ratio (OR) = 2.77, 95% confidence interval (CI) 1.35–5.66), use of a humidifier in the child's room (OR = 1.89, 95% CI 1.30–2.74), and the presence of an electric heating system in the home (OR = 2.27, 95% CI 1.42–3.65). The presence of other smokers in the home was not quite significant (OR = 1.82, 95% CI 0.98–3.38). A history of pneumonia, the absence of breast feeding, and a family history of asthma were also significant risk factors. In a separate unmatched multivariate analysis of subjects who had worn the nitrogen dioxide badge, there was a dose-response relation between nitrogen dioxide (in parts per billion) and asthma. These results confirm the role of susceptibility factors in asthma and show that indoor environmental factors contribute to the incidence of asthma. *Am J Epidemiol* 1993;137:834–44.

air pollutants; asthma; child; environment; household articles; nitrogen dioxide; tobacco smoke pollution

Concern has arisen in recent years about indoor air pollution as a risk factor for asthma (1). Pollutants in the home are numerous, and their sources, such as tobacco smoking, are encountered frequently. Moreover, the energy crisis of the 1970s provoked changes in the way houses are insulated and built; one consequence is that air exchange rates in energy-efficient "tight" and "super-tight" homes are substantially reduced in comparison with those in older conventional homes. Finally, it is recognized that most people spend 75–90 percent of their time indoors (2), a proportion that is likely to be greater in small children.

Indoor environmental factors that have received the most attention in the past are tobacco smoke and directly or indirectly measured nitrogen dioxide, mainly from gas appliances. The present study considered

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Abbreviations: CI, confidence interval; OR, odds ratio; ppb, parts per billion.

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these and other, less frequently studied potential risk factors for their relation to the incidence of asthma among 3- and 4-year-old children. The objective of the study was to estimate the contribution to asthma incidence of chemical, physical, and biologic indoor environmental factors, as well as family history of asthma and past infections, after accounting for personal susceptibility. A case-control study was carried out to meet this objective.

MATERIALS AND METHODS

Case ascertainment

Cases were 3- and 4-year-old children with a first-time diagnosis of asthma made by a pediatrician. We chose this age group to avoid the problem of differential diagnoses for asthma which is more likely at younger ages, and to allow for a plausible but reasonably short time period for risk factor assessment. Cases were recruited between January 1988 and December 1990 at the emergency room of Hôpital Sainte-Justine, the larger of two university-affiliated pediatric centers in Montreal, Quebec, Canada. A computerized roster is kept in the hospital's emergency room which includes the age of the child, the discharge diagnosis, and the child's medical record number. From this roster, 3- and 4-year-old children with a diagnosis compatible with any of those listed under *International Classification of Diseases*, Ninth Revision, code 493 had their hospital medical records checked for previous attendance with a similar diagnosis. Known (previously diagnosed) cases were rejected. A second screening for eligibility took place when the parents were asked whether the child had ever been diagnosed by a physician as having asthma. An additional criterion for eligibility was that the child reside in the greater Montreal region.

Control ascertainment

Controls were children of the same age (± month) and the same census tract (in the urban area) or postal code (in the rural area) as the case at the time of diagnosis. A census tract is defined in the *Canadian Census Dictionary* (3) as a small geostatistical unit including a mean of about 4,000 persons with maximum economic and social homogeneity. In rural areas surrounding the city, a postal code area indicates a region served by the post office or the postal branch. Controls were chosen from computerized family allowance files for the target region. The family allowance is a government stipend awarded to all families with children. Eligibility for the family allowance program is based on the following: a child must be less than 18 years of age and must reside in Canada. In addition, at least one parent must be a Canadian citizen, a person admitted to Canada as a permanent resident according to the terms of the law, or a person who has been admitted to the country as a visitor or who is holding a visiting permit for at least 1 year, and whose revenue is taxable (4). For reasons of cost, the latest available files from 1987 were used during 1988 and most of 1989. The 1989 files were used until the end of the study in 1990. All children who were eligible on the basis of age and census tract or postal code were enumerated from 1 to *n*. To choose the first control, we randomly generated a number between 1 and *n*. If, based on a search of readily accessible sources of information on addresses and telephone numbers, this control was not available, the procedure was repeated.

Data collection

The list of potentially eligible cases and controls was given to a first interviewer, who contacted the parents to confirm that the case was one with a first-time diagnosis by a physician and that the control had had no previous diagnosis of asthma made by a physician. If the parents were willing to participate, an appointment for the interview was made. A telephone interview was conducted by a second interviewer who was blind to the case/control status of the child. The interview had to take place for both cases and controls within 1 month of the case child's visit to the emergency room.

The questionnaire measured potential risk factors in yearly periods from birth to the time of diagnosis. These factors were grouped into three categories. The first category was personal susceptibility factors, family history of asthma, and past infectious diseases: the child's allergies. e.g., to food or clothing; parental and sibling asthma; and history of eczema, pneumonia, and tonsillectomy. The second category, environmental exposures in the home of a chemical nature, included maternal and paternal smoking; other smokers in the home; exposure to gas cooking appliances, kerosene space heaters, insulation material, and a fireplace or wood stove; and year of home construction. Other environmental factors of a physical nature were type of home heating system; whether the house contained a central humidifier, air purifier, or air conditioning; and whether a humidifier was used in the child's room. Other biologic factors assessed included family pets, wall-to-wall carpeting, the amount of dampness on the windows, and occupant density per room.

In addition, during the winter months, mostly the winter of the last study year, a subsample of 20 percent of study parents were asked to have their children wear a passive nitrogen dioxide monitoring badge (5) for 24 hours as part of a feasibility study. The main sources of emission of nitrogen dioxide in the home are gas stoves, gas- and kerosene-fueled space heaters, and, to a lesser extent, tobacco smoking (6). According to our instructions, the badge could either be worn by the child when he or she was awake and playing or left in the room while the child was sleeping. All consecutively interviewed parents during that study period were asked to use the badge, regardless of the child's case/control status.

Nitrogen dioxide from the filter badge was analyzed spectrophotometrically in parts per billion (ppb). The sensitivity of the badge was 66 ppb per hour, and in one study it was reported to have a precision of 5.9 percent (mean percentage difference, in ppb, between replicate measures; standard deviation, 5.4 percent) (7). The child's case/control status was unknown to the laboratory personnel who conducted the tests. The nitrogen dioxide results, in ppb, were categorized as follows: <0.5, 0.5–10, >10–15, and >15.

The third category included information on other personal and social factors such as the sex of the child, mother's and father's educational level (elementary school, high school or equivalent, college or equivalent, and postgraduate schooling), and breast feeding.

Some of the environmental exposures, such as type of heating and the presence of cooking appliances, wood stoves, fireplaces, central air conditioning, and central humidifiers, were also ascertained for any day-care center attended by the child, where applicable.

Statistical analysis

Conditional logistic regression (8) was used to analyze the matched data sets (EGRET package; Statistics and Epidemiology Research Corporation, Seattle, Washington). Odds ratios and their 95 percent confidence intervals were estimated. All statistical tests were two-sided. All variables were defined as categorical indicators. Categories were defined a priori. The independent contribution of each variable was assessed after controlling for personal susceptibility factors such as history of allergies and eczema. A multivarite model was developed that included all variables except those relating to insulation materials and the year of construction of the first home inhabited by the child, since parents often could not provide information on these factors. Nitrogen dioxide was not included either, because only 140 subjects had their child wear the badge as instructed. However, using the 140 subjects with nitrogen dioxide measurements, an unconditional logistic regression analysis was conducted that included nitrogen dioxide and all of the variables that made an independent contribution in the conditional multivariate model.

Response

There were 631 confirmed eligible case children; parents of 627 were successfully

interviewed, and four families refused to participate. However, 457 cases were used in the analysis because the controls for 170 of the cases could not be interviewed within 1 month of case ascertainment. This was mostly due to a delay in receiving and difficulty reading the computer tapes of the family allowance files at the beginning of the study and during the study's second year. Cases not included in the analysis were similar to those included with respect to age and sex distribution, the proportion with past allergies, and mother's smoking. On the other hand, we had to approach 1,188 families to obtain interviews from 457 controls: 598 families were no longer living at the address listed in the files, 53 had a confidential telephone number, 49 were known cases of asthma, 21 refused to participate, and 10 were not fluent in French or English.

Parents of 82 cases and 102 controls (20 percent of the study subjects) were asked if they would have their child wear the passive monitoring badge. Parents of two cases and five controls refused, and parents of 61 cases (61/80, 76.2 percent) and 79 controls (79/97, 81.4 percent) returned the badge.

RESULTS

All results for environmental factors (except for nitrogen dioxide, as explained above) are based on the presence or absence in the home of a given risk factor throughout the period between birth and the case's calendar date of diagnosis.

Child allergies (odds ratio (OR) = 1.88, 95 percent confidence interval (CI) 1.27–2.77) and eczema (OR = 2.06, 95 percent CI 1.37–3.10), each adjusted for the other, were independent risk factors for asthma. The percentages of parents and siblings with asthma and the prevalence of past infectious diseases for cases and controls are shown in table 1, along with matched odds ratios adjusted for child allergies and eczema. There were more cases than controls with a family history of asthma, as well as past pneumonia and tonsillectomy. All odds ratios were statistically significant.

Similar results for chemical, physical, and biologic factors in the home are shown in table 2. Slightly more case mothers than control mothers smoked, but the reverse was true for fathers. The adjusted odds ratio for a mother's smoking more than 20 cigarettes daily in comparison with not smoking was increased, at 1.60, and was almost significant ($p = 0.06$). There were twice as many other smokers in the homes of cases as in the homes of controls, and the odds ratio associated with this variable was significantly increased.

In analyses for which results are not shown, we derived a score based on the number of cigarettes smoked daily and the duration of the habit during the period between birth and time of diagnosis. Since smoking habits did not vary much, this analysis did not substantially change the results shown above.

The odds ratios for nitrogen dioxide increased with each categorized level in comparison with the baseline category. In the subgroup tested with the sampler, only six families had a gas stove. However, five of these six were in the highest category of

TABLE 1. Prevalence of a family history of asthma and past infectious diseases, matched odds ratios adjusted for allergy and eczema, and 95% confidence intervals among 457 cases diagnosed with asthma and 457 controls matched for age and area of residence, Montreal, Quebec, Canada, 1988–1990

Factor*	Cases (n = 457) (%)	Controls (n = 457) (%)	Matched odds ratio	95% confidence interval
Father with asthma	8.7	2.8	2.86	1.51–5.41
Mother with asthma	9.8	5.2	1.89	1.12–3.19
Siblings with asthma	9.6	5.4	1.91	1.15–3.19
Tonsillectomy	4.6	1.7	3.69	1.46–9.36
Pneumonia	24.0	8.3	3.31	2.17–5.06

* Factors are defined as yes versus no.

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TABLE 2. Prevalence of indoor chemical, physical, and biologic factors, matched odds ratios adjusted for allergy and eczema, and 95% confidence intervals among 457 cases diagnosed with asthma and 457 controls matched for age and area of residence, Montreal, Quebec, Canada, 1988–1990

Factor*	Cases (n = 457) (%)	Controls (n = 457) (%)	Matched odds ratio	95% confidence interval
Mother smoking (cigarettes/day)				
0	59.8	63.3	1.00	
>0 to ≤20	30.2	29.6	1.11	0.82–1.51
>20	9.9	7.0	1.60	0.96–2.65
Father smoking (cigarettes/day)				
0	64.9	60.2	1.00	
>0 to ≤20	32.9	38.0	0.80	0.59–1.09
>20	2.2	1.7	1.20	0.46–3.12
Other smokers in the home	14.2	7.2	2.23	1.37–3.63
NO_2† (ppb)				
0	24.5	39.2	1.00	
>0.5 to ≤10	18.0	43.0	0.75	0.29–1.93
>10 to ≤15	13.1	10.1	2.51	0.75–8.35
>15	44.2	7.5	10.54	3.48–31.89
Gas cooking appliance	6.6	5.2	1.33	0.68–2.58
Kerosene space heater	2.0	2.8	0.67	0.27–1.64
Mineral wool insulation‡	86.6	80.1	1.67	0.98–2.85
Urea formaldehyde foam insulation§	2.2	1.9	1.26	0.31–5.17
Fireplace	21.4	24.3	0.82	0.58–1.17
Wood stove	16.6	17.7	0.91	0.62–1.32
Year of construction of first home inhabited by the child‖				
After 1970 versus before	53.4	45.4	1.48	1.10–1.99
After 1980 versus before	20.7	14.0	1.54	1.04–2.29
Electric heating system	86.2	75.9	2.02	1.38–2.94
Central humidifier	8.5	11.8	0.67	0.42–1.07
Central air purifier	14.9	15.6	0.99	0.58–1.69
Central air conditioning	6.7	9.4	0.68	0.41–1.13
Humidifier in child's room	67.6	55.8	1.73	1.28–2.34
Wall-to-wall carpets	56.5	55.3	1.03	0.71–1.50
Dampness on windows	63.6	67.9	0.85	0.58–1.26
Occupant density <1 person/room	77.9	81.6	0.79	0.55–1.12
Pets	43.7	43.5	1.05	0.79–1.38

* Factors are defined as yes versus no if not otherwise specified.
† Based on 61 cases and 79 controls; odds ratio is unmatched.
‡ Based on 202 cases and 221 controls; odds ratio is unmatched.
§ Based on 185 cases and 216 controls; odds ratio is unmatched.
‖ Based on 365 cases and 370 controls.

nitrogen dioxide measurements. The mean ppb value for nitrogen dioxide in the 134 homes without a gas stove was 9.20 (standard deviation, 7.57); in the six homes with a gas stove, it was 17.16 (standard deviation, 8.26).

There was no notable difference between cases and controls with regard to the prevalence of other sources of chemical emissions, such as gas cooking appliances, space heaters, insulating material, fireplaces, and wood stoves. Recently built houses could be sources of more chemicals than older ones; in this study, the risk of developing asthma was greater if the first home inhabited by the child was built more recently than if it was built earlier.

Eighty percent of all study parents reported having a centralized electric heating system in the home, but more cases were exposed to it than controls; a twofold increased risk was associated with having such

a system in comparison with not having one. Among the other factors listed in table 2, only the presence of a humidifier in the child's room prior to the time of diagnosis was significantly associated with asthma.

Table 3 shows the association of other personal and socioeconomic factors with asthma. Mother's higher education was a statistically significant risk factor for asthma, and control mothers breast-fed their child slightly more often than case mothers did. Not shown in the table is the distribution of cases and controls according to language spoken at home: among case families, 85.1 percent spoke French, 3.1 percent spoke English, and 11.8 spoke another language. Among control families, these percentages were 80.5, 11.8, and 7.7, respectively. Among mothers of cases, 4.6 percent were 20 years of age or less, as compared with 1.9 percent among mothers of controls. Among case mothers, 76.1 percent were born in Québec, 6.7 percent were born in the West Indies, and 2 percent or less were born in each of 15 other regions. Among controls, 80.9 percent of mothers were from Quebec, 3.9 percent were from the West Indies, 3.7 percent were from Western Europe, and less than 2 percent were from each one of 13 other countries.

In the final conditional logistic regression model, all variables from the above tables, except the ones related to insulation materials, year of home construction, and nitrogen dioxide, were entered into the model. Variables which made an independent contribution ($p \leq 0.05$) and those which were marginally significant ($p \leq 0.10$) are shown in table 4.

Father and sibling asthma were independent risk factors for asthma, as was a past history of pneumonia. Having had a tonsillectomy was associated with an increased risk (OR = 2.83) that was marginally significant ($p \leq 0.06$). A mother's heavy smoking contributed significantly to the incidence of asthma (OR = 2.77), and the presence in the home of smokers other than the parents was associated with an odds ratio of 1.82, which did not quite reach statistical significance ($p = 0.056$). Among the other environmental factors, two were associated with increased and statistically significant odds ratios: the presence of a humidifier in the child's room (OR = 1.89) and having an electric heating system in the home (OR = 2.27). Finally, the absence of breast feeding significantly increased a child's risk of asthma. The mother's having a university education was a marginally significant risk factor ($p \leq 0.07$), whereas the presence of central air conditioning was a protective factor, likewise marginally significant ($p \leq 0.08$).

Multivariate unconditional logistic regression was carried out for the 140 subjects who had nitrogen dioxide measurements; the analysis included nitrogen dioxide and the variables retained in the final conditional model. The odds ratios for the nitrogen dioxide categories (defined as >0.5–10, >10–15, and >15 ppb, in comparison with a zero level) were 0.95 (95 percent CI 0.31–2.95), 3.85 (95 percent CI 0.92–16.09), and 19.87 (95 percent CI 4.75–83.03), respectively.

Among all study children, 52.8 percent attended day-care centers during the study period; thus, our power to detect associa-

TABLE 3. Prevalence of other personal and socioeconomic factors, matched odds ratios adjusted for allergy and eczema, and 95% confidence intervals among 457 cases diagnosed with asthma and 457 controls matched for age and area of residence, Montreal, Quebec, Canada, 1988–1990

Factor*	Cases (n = 457) (%)	Controls (n = 457) (%)	Matched odds ratio	95% confidence interval
Male	55.8	54.0	1.02	0.78–1.33
Mother has university education	23.7	17.8	1.49	1.03–2.13
Father has university education	28.2	24.1	1.21	0.87–1.68
No breast feeding	50.9	47.0	1.24	0.93–1.64

* Factors are defined as yes versus no.

TABLE 4. Final conditional logistic regression model* for the analysis of risk factors among 457 cases diagnosed with asthma and 457 controls matched for age and area of residence, Montreal, Quebec, Canada, 1988–1990

Factor†	Odds ratio	95% confidence interval
Child is allergic	2.52	1.50–4.21
Child had eczema	1.68	1.01–2.81
Asthma in father	2.39	1.13–5.04
Asthma in siblings	2.26	1.19–4.29
Child had pneumonia	3.12	1.92–5.09
Child had tonsillectomy	2.83	0.92–8.71
Mother smoking (cigarettes/day)		
>0 to ≤20 versus 0	1.16	0.77–1.76
>20 versus 0	2.77	1.35–5.66
Other smokers in the home	1.82	0.98–3.38
Humidifier in child's room	1.89	1.30–2.74
Electric heating system	2.27	1.41–3.65
Central air conditioning	0.56	0.29–1.08
Mother has university education	1.60	0.96–2.67
No breast feeding	1.47	1.02–2.13

* All variables from tables 1–3 are present in the model (except NO_2, insulation material, and year of construction of the house), but only the odds ratios with p values ≤0.10 are shown.

† Factors are defined as yes versus no, unless otherwise specified.

tions between asthma and environmental exposures encountered in day-care centers was limited. Indeed, none of the estimated odds ratios were statistically significant. However, among cases and controls attending their first day-care center, the risk of asthma was increased when the day-care center had an electric heating system in comparison with other systems (OR = 1.32, 95 percent CI 0.81–2.16); this was also the case for the second day-care center attended (OR = 1.59, 95 percent CI 0.69–3.65).

DISCUSSION

In the literature, there appears to be no other incident density case-control study of new cases of asthma diagnosed by pediatricians among 3- and 4-year-old children. Previous studies were largely cross-sectional in design and included elementary school-aged children (generally aged 6–14 years) who, according to parental reporting, had asthma or a closely related respiratory problem such as wheezing or whistling, or had had some type of chest illness in the previous year. However, most of the potential risk factors for childhood asthma considered in the present report have been studied before. Allergies and eczema were considered as manifestations of atopy, which is strongly associated with asthma in all age groups (9). History of asthma in the family was an independent risk factor in these data, and this is generally consistent with previous findings (10–17). This was also true for pneumonia in infancy (11–13, 18, 19) and tonsillectomy (19).

Many studies have shown a statistically significant relation between passive smoking and childhood asthma (10, 15, 20, 21–28), but more have not (12–14, 16, 18, 19, 29–34). Often, a single variable was used, such as the presence or absence of parental smoking or the presence of one or two smokers, whereas in the present study, the mother's and father's levels of smoking were analyzed separately, in addition to the presence or absence of other smokers (often baby-sitters) in the home. Increased risks in this study may be due to children being younger and belonging to a narrower age group than children in most previous studies and to the physician diagnosis of disease, which is likely to have been much more uniform than that in any other study.

Reduced efficacy of lung defenses and airway injury have been postulated as mechanisms for the effects of nitrogen dioxide on respiratory health (35). From clinical studies, the short-term effects of nitrogen dioxide on asthmatics are not well characterized, although decrements in lung function have been observed. In epidemiologic studies, the focus has mainly been on exposure to nitrogen dioxide in the home environment, and the results are inconclusive. Two studies found a significant association between gas cooking appliances and the prevalence of asthma in children (21, 28), but other studies did not (12, 15, 18, 23, 24, 31–33, 36, 37). When quantitative area sampling measure-

ments of nitrogen dioxide were made in the home using diffusion tubes (22, 34, 37, 38), only once was there an association between nitrogen dioxide in the living room and childhood asthma (22). These inconsistent results are probably due to misclassification of exposure and outcome and to small study sizes (35). The probability of misclassification of residential exposure to nitrogen dioxide has recently been documented (39): It was shown to depend on the number of samples taken and on the categories used to classify results. Having a lesser number of samples was associated with substantial variability when true mean exposure was greater than 15 ppb.

Given these results, misclassification of exposure is likely to have occurred in the present study, wherein only one sample was taken on a subset of 140 subjects. However, a dose-response relation was suggested. This may be due to the use of a personal sampler s opposed to the use of a static sampler in revious studies, and to the likelihood that younger children are more susceptible to increased levels of nitrogen dioxide. In the study by Neas et al. (37), where repeated nitrogen dioxide measurements were made in different rooms with Palmes' passive diffusion tubes, the average nitrogen dioxide value for a household without a major indoor nitrogen dioxide source was 8.6 ppb (standard error, 0.2), whereas it was 23.5 ppb (standard error, 0.4) in homes where a major source existed. These results are quite comparable to those of the present study.

Other studies with different measures of home dampness have consistently found an association with asthma (28, 32, 40–43), with one exception (34). Dampness on windows was the variable used in the present study, and it was probably too vague a measure. Occupant density as a measure of crowding was not significant in this study or in many others (18, 20, 32, 33, 38). Pets are considered a definite risk factor for asthma by clinicians (44); thus, it was surprising to find that only a few studies asked about their esence (14, 28, 33, 38, 40). Moreover, ither in the present study nor in any of the previous studies was there an association between the presence of pets and the incidence of asthma. In this study, at least, the young age of the subjects may explain the negative finding, since younger children may not have had the time to be sensitized.

An interesting finding of this study is that the use of a humidifier in the child's room prior to diagnosis of asthma was strongly associated with the development of asthma. One could interpret these findings as an effect rather than a cause; that is, children with past allergies or past episodes of infection have had previous medical care, and their parents may have been urged to buy a humidifier. Thus, the humidifier use would simply be a proxy for respiratory symptoms that were not yet recognized as asthma. However, we adjusted in the analyses for personal susceptibility, past infections, and family history. Moreover, in the subgroup of 507 children without any allergies or past infections, the unmatched odds ratio for asthma associated with having a humidifier in the child's room was 1.57 (95 percent CI 1.07–2.31).

In another Canadian study, Dekker et al. (28) reported an increased odds ratio associated with the use of a humidifier in the home, but it seems that this variable was use of a central humidifier. In Montreal, winters are long and very cold, and heating systems work continuously; as a result, indoor air is often dry. There is a belief among the lay public that some humidity is necessary for avoiding respiratory illness in children. We can only speculate about the mechanism by which a humidifier may be a risk factor for the development of asthma. Growth of biologic agents in the ducts of the humidifier is one possibility (45, 46). It is also possible that a humidifier could increase the level of house dust mites implicated in the development of asthma (47), since the conditions for their growth are similar to those for fungi (48). However, the outdoor climatic conditions favoring the growth of mites are high humidity and moderate temperature (49), and these conditions are rarely met in Montreal.

Although an electric heating system was never found to be significant in any of the few studies that have considered it as a potential risk factor for childhood asthma (21,

24, 28, 33, 40), it was an independent risk factor in this study. Unfortunately, sample size became too small to determine whether the delivery of heat through forced air, radiant heat, or water radiators modified that effect.

It is not clear why the present study did not find that boys were at increased risk of asthma because many previous studies did (12, 19, 22, 25, 50), although not all (20). Finally, contrary to most studies (14, 19, 25, 40, 50, 51), the present study showed an association between asthma and breast feeding. Only one other study reported that breast feeding was a protective factor (19). The younger age of our study subjects is a likely explanation for these discrepancies. Indeed, the protective effect may not last beyond early infancy.

Misclassification of outcome is a potential concern in most studies of childhood asthma, including this one. However, had many cases not been asthmatics and many controls underdiagnosed, it is unlikely that the study would have shown increased risks for markers of atopy, family history, and previous infections. Potential selection bias needs to be addressed. Controls living in the same census tract were considered a reasonable choice for the study base. However, only families who still resided at the address given in the files were sampled as controls. If the studied factors were associated with mobility, then the proportion of controls exposed to these factors would have been underestimated in this study. There are some indications that this was not the case. For instance, a recent national survey (52) showed that among Quebec women aged 20–44 years in 1986, 37.5 percent were regular smokers, which is identical to the proportion found among control mothers in this study. In addition, in 1983, the prevalence of asthma in 3- and 7-year-old children in Montreal was estimated to be 6.4 percent (53), which is close to the 5.4 percent found among controls in the present study. We also note that socioeconomic factors, which may be associated with mobility, were controlled for in the analysis.

In conclusion, this incident density case-control study showed that even after accounting for personal susceptibility, family history, past infections, and factors related to the indoor environment contribute significantly to the incidence of asthma. For future studies to have a greater impact on public health, it will be necessary to assess exposure-response relations and to relate findings to suggested protective standards. Obtaining reliable quantitative measurements will be the challenge to future studies.

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